In the next series of observations, the rays were refracted from air into glass. The electric beam was rendered parallel with the help of a glass lens ($f = 4$ cm.). The beam was incident on the *plane* face of the semi-cylinder. As the cylinder itself focussed the refracted beam, the objective hitherto used in conjunction with the receiver was dispensed with.

i.	r.	Mean value of r.	μ.
40°	18° 19 18	18° 20′	2·04
50°	22° 23 22° 30′	22° 30′	2·00
65°	25° 30′ 26° 27	26° 10′	2·05

Mean value of $\mu = 2{\cdot}03$ .... (4).

The different values of μ obtained are given below :—

From total reflection from a single semi-cylinder, 2·08 .... (1)
" " " two semi-cylinders .. 2·04 .... (2)
From refraction from glass into air .... 2·04 .... (3)
" " air into glass .... 2·03 .... (4)

The frequency of vibration was of the order 10^{10}.

The value of the optical index of the glass determined by the total reflection method was found to be

$$\mu_D = 1{\cdot}53.$$

"On the Influence of the Thickness of Air-space on Total Reflection of Electric Radiation." By JAGADIS CHUNDER BOSE, M.A., D.Sc., Professor of Physical Science, Presidency College, Calcutta. Communicated by LORD RAYLEIGH, F.R.S. Received November 15,—Read November 25, 1897.

In my preliminary experiments on the determination of the index of refraction of various substances for electric radiation, I used a

single semi-cylinder of the given substance; the electric ray was refracted from the denser medium into air, and at the critical angle of incidence it underwent total reflection. The experiment was repeated with two semi-cylinders separated by a parallel air-space. With light waves an extremely thin air-film is effective in producing total reflection. But a question might arise whether waves a hundred thousand times as long would be totally reflected by films of air, and, if so, it would be interesting to find out the minimum thickness of air-space which would be effective in producing this result. This point was raised by Professor Lodge, at the discussion on my paper "On a Complete Apparatus for the Study of the Properties of Electric Waves," read before the Liverpool meeting of the British Association last year. I have for some time past been engaged in an investigation on this subject. The factors which are likely to determine the effective thickness of air-space for total reflection are: (1) the index of refraction of the refracting substance; (2) the angle of incidence; (3) the wave-length of the incident electric radiation. In the following investigation, I have studied the influence of the angle of incidence and of the wave-length in modifying the thickness of the effective air-space. The refracting substance used was glass.

I. *Influence of the Angle of Incidence.*

The great experimental difficulty in these investigations lies in the fact, that there is at present no receiver for electric radiation which is very sensitive, and at the same time strictly metrical in its indications. This difficulty is further complicated by the fact that the intensity of the electric radiation cannot be maintained absolutely constant. For these reasons, it is extremely difficult to compare the results obtained from different sets of observations. Attempts have been made in the following experiments to remove, to a certain extent, some of these difficulties.

Two semi-cylinders of glass, with a radius of 12·5 cm., were placed on the spectrometer circle. The plane faces were separated by a parallel air-space. The radiator was placed at the principal focus of one of the semi-cylinders; the rays emerged into the air-space as a parallel beam, and were focussed by the second semi-cylinder on the receiver placed opposite the radiator. Electric radiation was produced by oscillatory discharge between two small circular plates 1·2 cm. in diameter and an interposed platinum ball 0·97 cm. in diameter.

The two semi-cylinders were separated by an air-space 2 cm. in thickness; this thickness was found to be more than sufficient for total reflection. The critical angle for glass I found to be 29°. I commenced my experiments with an angle of incidence of 30°

(slightly greater than the critical angle). The receiver, which was placed opposite the radiator, remained unaffected as long as the rays were totally reflected. But on gradually diminishing the thickness of air-space by bringing the second semi-cylinder nearer the first (always maintaining the plane surfaces of the semi-cylinders parallel), a critical thickness was reached when a small portion of the radiation began to be transmitted, the air-space just failing to produce total reflection. The *beginning* of transmission could easily be detected and the critical thickness of air determined with tolerable accuracy. The slight discrepancy in the different determinations was due to the unavoidable variation of the sensitiveness of the receiver. When the thickness of air was reduced to 14 mm., the receiver began occasionally to be affected, though rather feebly. But when the thickness was reduced to 13 mm. there was no uncertainty; a measurable, though small, portion of the radiation was now found to be always transmitted.

I now increased the angle of incidence to 45°, and observed that the minimum thickness, which at 30° just allowed a small portion of radiation to be transmitted, was not sufficiently small to allow transmission at the increased angle of incidence. The thickness had to be reduced to something between 10·3 mm. and 9·9 mm. for the beginning of transmission.

With an angle of incidence of 60°, the minimum thickness for total reflection was found to be between 7·6 mm. and 7·2 mm.

Angle of incidence.	Minimum thickness of air for total reflection.
30°	Between 14 and 13 mm.
45	,, 10·3 and 9·9 mm.
60	,, 7·6 and 7·2 mm.

The minimum effective thickness is thus seen to undergo a diminution with the increase of the angle of incidence.

II. *The influence of the Wave-length.*

In the following experiments I kept the angle of incidence constant, and varied the wave-length. I used three different radiators, A, B, and C; of these A emitted the longest, and C the shortest waves.

The following method of experimenting was adopted as offering some special advantages. If a cube of glass be interposed between the radiator and the receiver placed opposite to each other, the

radiation striking one face perpendicularly would be transmitted across the opposite face without deviation and cause a response in the receiver. If the cube be now cut across a diagonal, two right-angled isosceles prisms will be obtained. If these two prisms were now separated slightly, keeping the two hypotenuses parallel, the incident radiation would be divided into two portions, of which one portion is transmitted, while the other portion is reflected by the air film in a direction (see fig. 1) at right angles to that of the

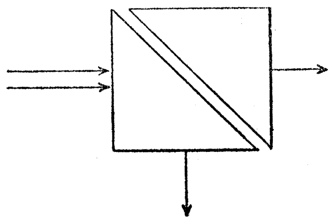

FIG. 1.—Section of the two prisms.

incident ray, the angle of incidence at the air-space being always 45°. The transmitted and the reflected portions would be complementary to each other. When the receiver is placed opposite to the radiator, in the A position, the action on the receiver will be due to the transmitted portion; but when the receiver is placed at 90°, or in the B position, the action on the receiver will be due to the reflected portion. The advantage of this method is that the two observations for transmission and reflection can be successively taken in a very short time, during which the sensitiveness of the receiver is not likely to undergo any great change. In practice three readings are taken in succession, the first and the third being taken, say, for transmission and the second for reflection.

I shall now give a general account of the results of the experiments. When the prisms are separated by a thickness of air-space greater than the minimum thickness for total reflection, the rays are wholly reflected, there being no response of the receiver in position A, but strong action in position B. As the thickness is gradually decreased below the critical thickness, the rays begin to be transmitted. The transmitted portion goes on increasing with the diminution of the thickness of air-space, there being a corresponding diminution of the reflected component of the radiation. When the thickness of the air-space is reduced to about 0·3 mm., no reflected portion can be detected even when the receiver is made extremely sensitive. The reflected component is thus practically reduced to zero, the radiation being now entirely transmitted; the two prisms, in spite of the breach due to the air-space, are electro-optically con-

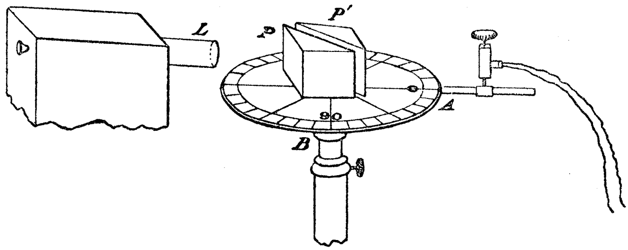

FIG. 2.—L is the lens to render the incident beam parallel; P, P', are the right-angled isosceles prisms; A and B are the two positions of the receiver. The receiver-tube is not shown in the diagram.

tinuous. This is the case only when the two prisms are made of the same substance. If the second prism be made of sulphur, or of any other substance which has either a lower or a higher refractive index, there is always found a reflected portion even when the two prisms are in contact.

Another interesting observation can be made by separating the prisms for total reflection. There would now be no transmitted portion. But if a thin piece of cardboard or any other refracting substance be now interposed in the air-space, a portion of the radiation will be found to be transmitted, and it will be found necessary to separate the prisms further to reduce the transmitted portion to zero.

Having given a general account of the experiments, I shall now describe the method of procedure. The radiator tube was provided with an ordinary lens whose focal distance for electric radiation is about 4 cm. The beam thus rendered approximately parallel fell perpendicularly on the face of the glass prism. The two prisms were made by cutting a cube of glass—an ordinary paper weight—across a diagonal. The size of the cube was 4·5 cm. on each side.* One prism was fixed on the spectrometer circle; the other could be moved so as to vary the thickness of the interposed air-space between the two sections very gradually. The separation was simply effected by means of ordinary cards. The cards used were of uniform thickness, each card being 0·45 mm. in thickness. A certain number of cards were taken and placed between the prisms with their surfaces in contact with the hypotenuses. The cards were then carefully withdrawn, leaving the prisms separated by a thickness of air equal to the thickness of the given number of cards. It would, of course, be an improvement to have a micrometer screw by which the thickness may be gradually increased.

* Larger prisms would have been preferred, had they been available. The prisms after cutting were found to be approximately isosceles, the angles being 90°, 46°, and 44°.

Observations were now taken to determine the minimum thickness of air for total reflection for different wave-lengths, the angle of incidence being in all cases kept at 45°. Three radiators, R_1, R_2, R_3, were used. I have not yet made determinations of the lengths of wave emitted by these radiators, but it will be seen from the dimensions of the radiators that the waves emitted by R_1 are the longest and those emitted by R_3 the shortest. The oscillatory discharge in R_1 took place between two circular plates 1·2 cm. in diameter and an interposed ball of platinum 0·97 cm. in diameter. The radiators were enclosed in a tube 3·8 cm. in diameter.

In the radiator R_2, the discharge took place between two beads of platinum and an interposed sphere the same as in R_1. The distance between the sparking surfaces was 1·01 cm.

In the radiator R_3, sparking took place between two beads and an interposed sphere 0·61 cm. in diameter. The distance between the sparking surfaces was 0 76 cm.

One prism was fixed on the spectrometer circle, and the other was at first placed somewhat apart from it; the distance was now gradually reduced till the air-space just ceased to reflect totally, when a small portion of radiation began to be transmitted. The beginning of transmission was detected by the receiver, which was placed in the A position. The detection of the beginning of transmission is, as has been said before, somewhat dependent on the sensitiveness of the receiver.

Radiator.	Distance between sparking surfaces in mm.	Minimum thickness for total reflection.	
R_1	—	Between 10·3 and 9 9 mm.......	(a)
R_2	10·1	,, 7·6 and 7·2 mm.......	(b)
R_3	7·6	,, 5·9 and 5·4 mm.......	(c)

From the above results it is seen that the effective thickness of the totally reflecting air-space increases with the wave-length. If the wave-lengths are proportional to the distance between the sparking surfaces which give rise to the oscillatory discharge, the wave-lengths in (b) and (c) are in the ratio of 101 : 76. This is not very different from the ratio of the corresponding minimum thicknesses of the totally reflecting air-space.

III. *On the Relation between the Reflected and the Transmitted Components of Radiation when the Thickness of Air-space undergoes Variation.*

In the general account of the experiments, I have said that as the thickness of air-space is gradually reduced the intensity of the

transmitted portion of radiation is increased, while there is a corresponding diminution of the intensity of the reflected portion. This I have been able to verify qualitatively from numerous observations. But in making quantitative measurements many serious difficulties are encountered, owing to the difficulty of maintaining the intensity of radiation, as well as the sensitiveness of the receiver, absolutely constant.

As regards the first, the intensity of the emitted radiation depends on the efficiency of the secondary spark, and the nature of the sparking surface. Keeping the primary current that flows through the Ruhmkorff coil constant, the efficacy of the secondary spark is very much affected by the manner in which the contact is broken in the primary circuit. If a vibrating interrupter is used, the break is apt to become irregular; the torrent of the secondary sparks also spoils the sparking surface of the radiator. For merely qualitative experiments the use of a vibrating interrupter is not so very prejudicial, as along with the ineffective discharges there are present some which are oscillatory. But where successive discharges are to give rise to radiation of equal intensity, it becomes necessary to avoid all sources of uncertainty. For these reasons I prefer a single break for the production of a flash of radiation. With some practice it is possible to produce a number of breaks, each of which is effective. If the surface at the break is kept clean, and the break is properly effected, successive flashes of radiation up to a certain number are about equally intense. When the sparking has been taking place for too long a time, the surface no doubt undergoes a deterioration. But twenty or thirty successive sparks are equally efficacious when sparking takes place between platinum surfaces. The use of a single flash of radiation is preferable on another account. The receiver at each adjustment responds to the very first flash, but becomes less sensitive to the subsequent flashes. The conditions of the different experiments are maintained similar, when the action on the receiver is due to a single flash of radiation, instead of the accumulated effect of an unknown number of flashes.

I give below the deflections of the galvanometer produced by four successive flashes of radiation.

(1)	115 divisions.
(2)	122 ,,
(3)	113 ,,
(4)	108 ,,

When very careful adjustments are made, the successive deflections are approximately equal. There are, however, occasional failures, owing either to the fault of the break, or loss of sensitiveness of the receiver.

More serious is the difficulty in connection with the receiver. With the improvements adopted there is no difficulty, under any circumstances, to make the receiver very highly sensitive; but it is extremely difficult to maintain the sensitiveness absolutely uniform. I have in my previous papers explained how the sensitiveness of the receiver depended on the pressure to which the spirals were subjected, and on the E.M.F. acting on the circuit; and how the loss of sensitiveness due to fatigue was counteracted by slightly increasing the E.M.F. For each receiver there is a certain pressure, and a corresponding E.M.F., at which for a given radiation the receiver is sensitive. Having obtained these conditions, the sensitiveness can be increased or decreased to almost any extent by a slight variation of either the pressure or the E.M.F. An increase of pressure produced by the advance of the micrometer press screw through a fraction of a millimetre would sometimes double the sensitiveness; similarly an increase of E.M.F. of even $\frac{1}{100}$ volt increases the sensitiveness to a considerable extent.

The nature of the difficulties in maintaining the sensitiveness of the receiver uniform will be understood from what has been said above. These difficulties are indeed great, and appear at first to be insuperable. But by very careful and tedious adjustments I was able on several occasions to obtain fairly satisfactory results, and was in hopes of ultimately obtaining symmetrical values from the galvanometer deflections. The setting-in of the rainy weather has unfortunately introduced other conditions unfavourable to the maintenance of uniformity of the sensitiveness of the receiver. Owing to the excessive damp and heat the spirals get rusty in a short time, and variation in the sensibility is produced by the altered condition of the surface of the sensitive layer. The results of certain experiments I have carried out lead me to hope that this difficulty will, to a certain extent, be removed by covering the sensitive surface with a less oxidisable coating.

The deflections produced in the galvanometer can only be taken approximately proportional to the intensity of the absorbed radiation. It would be better to observe the diminution of the resistance produced by the incident radiation. This may be done with the help of a differential galvanometer and a balancing resistance.

G is a high resistance differential galvanometer, with two sets of electrodes, A, B; C, D; one pair of electrodes is in series with the receiver, and the other with a resistance box. When the receiver is adjusted to respond to the electric radiation, a weak current flows through it. The same E.M.F. acts on both the circuits. The compensating current, produced by a proper adjustment of the resistance of the box, brings the spot of light back to zero. The resistance of the box is equal or proportional to the resistance of the receiver.

When radiation is absorbed by the receiver the resistance is decreased and this diminution of the resistance is found from the new balancing resistance.

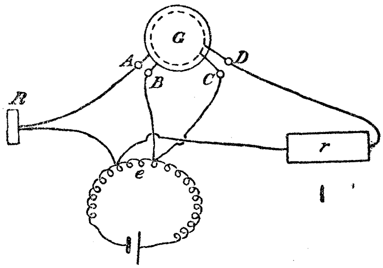

FIG. 3.—G, the differential galvanometer; R, the receiver; r, the resistance box.

All observations agreed in showing that as the thickness of air-space was gradually decreased, the transmitted component was increased, with a corresponding decrease of the reflected portion. I give below two sets of observations, in which the receiver acted better than usual. The results are to be taken more as qualitative, as no reliance can be placed on the sensibility of the receiver being absolutely uniform.

Radiator R_2; distance between the sparking surfaces = 10·1 mm.

Thickness of air-space in terms of number of cards.	Thickness in mm.	Galvanometer deflection due to the reflected portion.	Galvanometer deflection due to the transmitted portion.
1	0·45	0 or very slight.	Against the stop.
2	0·90	Slight	,, ,,
4	1·8	80	160
8	3·6	145	150
10	4·5	150	120
12	5·4	160	100
16	7·2	Against the stop	30
18	8·1	,, ,,	0

It is seen from the above, that as the thickness of the air-space was gradually increased, the reflected component increased, while the transmitted portion decreased. The minimum thickness for total reflection was found to be about 8 mm. When the thickness of air-space was reduced to about half this thickness (slightly less than half) the reflected and the transmitted portions seemed to be about equal.

With the radiator R_1 the minimum thickness for total reflection was found to be about equal to the thickness of 22 cards (9·9 mm.). When the thickness of air-space was reduced to the thickness of 10 cards (4·5 mm.) the reflected and the transmitted portions seemed to be about equal. As two experiments immediately following each other are more likely to be comparable, the experiments were so arranged that the observation of deflection for *transmission* with a certain thickness of air followed the observation for *reflection* with a different thickness, the corresponding deflections being about equal. As stated above, the reflected and the transmitted portions were approximately equal when the thickness of air was equal to the thickness of 10 cards. Keeping 10 as the mean, pairs of readings were taken with different thicknesses. For example, the reflection reading with a thickness of air equal to the thickness of 4 cards was followed by taking a reading for transmission, with a thickness of air equal to the thickness of 16 cards; the deflections produced in the two cases were about equal, *i.e.*, sixty-six divisions of the scale.

I append below a table showing the corresponding thicknesses of air (in terms of number of cards) which gave approximately equal deflections, the deflection in one case being due to the reflected component, and in the other case to the transmitted component. The receiver was made moderately sensitive, so that the deflections lay within the scale.

Thickness of air for reflection.	Thickness of air for transmission.	Deflection produced.
4	16	66
6	14	70
8	12	90
10	10	120

When the thickness of air was reduced to 0·45 mm., a deflection of

two divisions was obtained for the reflection reading. From this an approximate idea of the intensity of the reflected component may be obtained. Half the total radiation gave a deflection of 120 divisions. The intensity of the reflected component, with a thickness of 0·45 mm., is therefore 1/120th part of the total amount of incident radiation, on the assumption, which is only approximate, that the galvanometer deflections were symmetrical. When the thickness was reduced to 0·3 mm., no reflected component could be detected, though the receiver was made extremely sensitive.

"An Examination into the Registered Speeds of American Trotting Horses, with Remarks on their value as Hereditary Data." By FRANCIS GALTON, D.C.L., F.R.S. Received November 29,—Read December 16, 1897.

It is strange that the huge sums spent on the breeding of pedigree stock, whether of horses, cattle, or other animals, should not give rise to systematic publications of authentic records in a form suitable for scientific inquiry into the laws of heredity. An almost solitary exception to the disregard, shown by breeders and owners, of exact measurements for publication in stud books, exists in the United States with respect to the measured speed of "trotters" and "pacers" under defined conditions. The performance of 1 mile by a trotter, harnessed to a two-wheeled vehicle, carrying a weight of not less than 150 lbs. inclusive of the driver, in 2 minutes 30 seconds qualifies him for entry in the Trotting Register, giving him, as it were, a pass-degree into a class of horses whose several utmost speeds or "records" are there published. To avoid prolixity I will not speak particularly of pacers (pace = amble), since what will be said of the trotters applies in general principle to them also.

The great importance attached to high speed, and the watchfulness of competitors, have resulted in evolving a method of timing trotters which is generally accepted as authoritative. The length of the track is scrupulously measured, and numerous other conditions are attended to, that shall ensure the record being correct, with an attempted exactitude to the nearest quarter of a second. A race against time, even if exact to the nearest quarter of a second, is by no means so close a measure of the speed of a horse relatively to his competitors, as the differential method of ordinary races. The speed of 1 mile in 2′ 30″, or of 1760 yards in 150 seconds, is equivalent to about 12 yards in 1 second. Now, the length of a horse when extended at full trot is half as long again as his height at the withers—as I gather from the instantaneous photographs of Muybridge—and consequently is hardly ever as much as